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YBRID CORN

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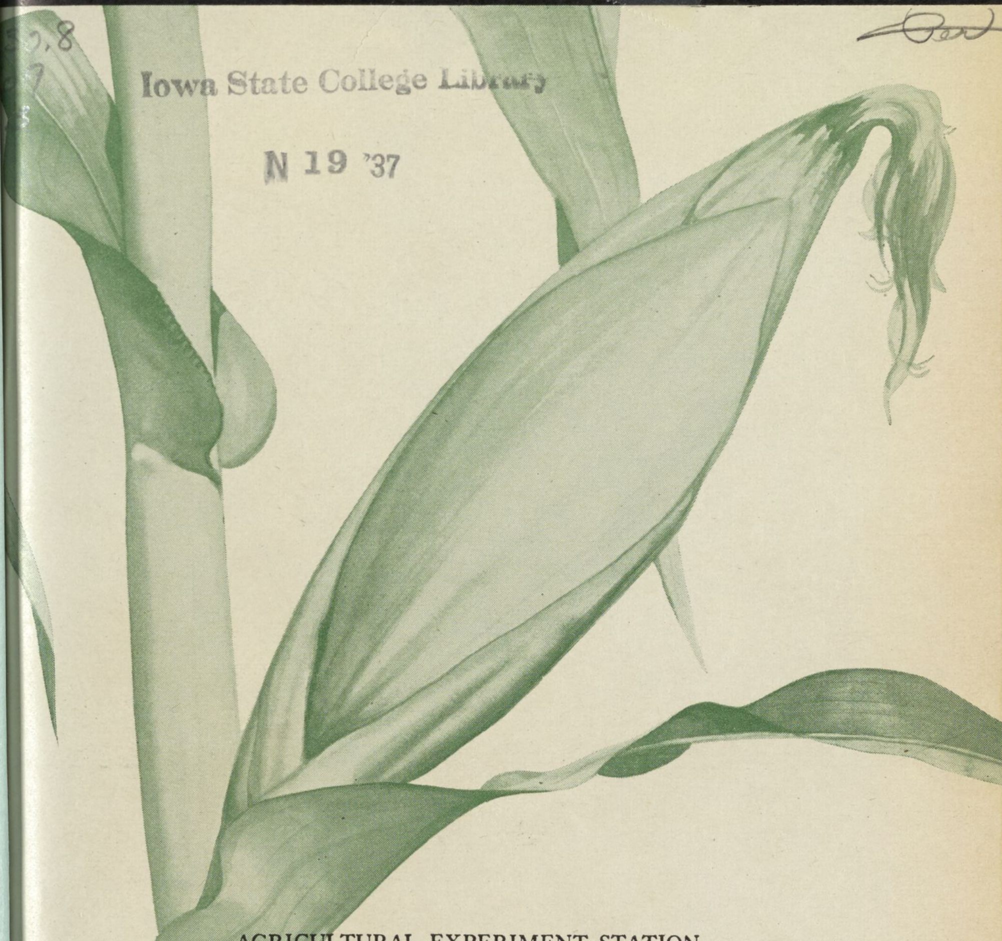

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BUREAU OF PLANT INDUSTRY, UNITED STATES DEPARTMENT OF AGRICULTURE
Cooperating
AMES, IOWA

IN IOWA

CONTENTS

HYBRID CORN IN IOWA[1]

By A. A. Bryan and R. W. Jugenheimer[2 3]

Hybrid corn is a comparatively recent development. Extensive breeding programs for the development of corn hybrids date from only about 1920—the Iowa program was begun in 1922. Despite the newness of hybrid corn, yield comparisons in the Iowa Corn Yield Test during the past 10 years have adequately demonstrated the superiority of certain hybrids over the best open-pollinated varieties. Results of these and other comparisons have awakened among growers a keen interest in the possibilities of hybrid corn.

Every grower is interested in obtaining large acre yields. The net profit from growing a bushel of corn is the difference between the cost of production and the selling price. Costs of producing an acre of corn are relatively constant, regardless of yield. The cost *per bushel*, therefore, is materially reduced with larger acre yields.

Comparisons in Iowa and in other Corn Belt states indicate that certain hybrids are more able to withstand drouth, wind, diseases, insects and other unfavorable conditions than the best of our previously existing varieties. These qualities reduce the hazards of corn production, with resultant benefits to the grower and the consumer.

This bulletin outlines the methods followed in corn improvement by the Iowa Agricultural Experiment Station in cooperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and describes the inbred lines and hybrids which have been developed and released for commercial production.

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[1] Farm Crops Subsection, Iowa Agricultural Experiment Station and the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, cooperating. Project 163 of the Iowa Agricultural Experiment Station.

[2] Agronomist and Agent, respectively, Division of Cereal Crops and Diseases, collaborators, Agronomy Section, Farm Crops Subsection, Iowa Agricultural Experiment Station.

[3] The writers hereby gratefully acknowledge the valuable assistance of Dr. M. T. Jenkins in the preparation of this bulletin. To Dr. Jenkins also is due the credit for selecting the inbred lines and making the hybrids described.

MODERN CORN BREEDING

In 1905 G. H. Shull, working at Cold Spring Harbor, Long Island, and E. M. East, working first at the Illinois Experiment Station and later at the Connecticut Experiment Station, started inbreeding corn independently. Publication of Shull's first results in 1908 and 1909 marks the beginning of modern corn breeding. Shull obtained large increases in yield from crosses between inbred lines. He outlined a method of breeding to utilize this increased vigor which involved (1) inbreeding for several generations to isolate desirable lines that breed true for the characters they possess, (2) determination of the lines which produce the best crosses and (3) utilization of the better crosses for the commercial production of corn.

PRODUCTION OF INBRED LINES

The best hybrid corn is produced by crossing selected inbred lines. The first requisite of a hybrid corn program, therefore, is to develop such lines. These lines are obtained by self-pollinating or "selfing" the corn plant through several generations. Self-pollination is the process of applying to the silks of a corn plant pollen from the same plant. Hand or artificial pollination will be described later.

RESULTS OF INBREEDING

Inbreeding in corn results in a marked decrease in vigor and productivity. Theoretically, one-half of the total decrease in productivity from the open-pollinated plant to the pure line will occur in the first generation of selfing, one-half of the remainder in the second generation and so on until, finally, there is no further noticeable reduction. On the average, about 97

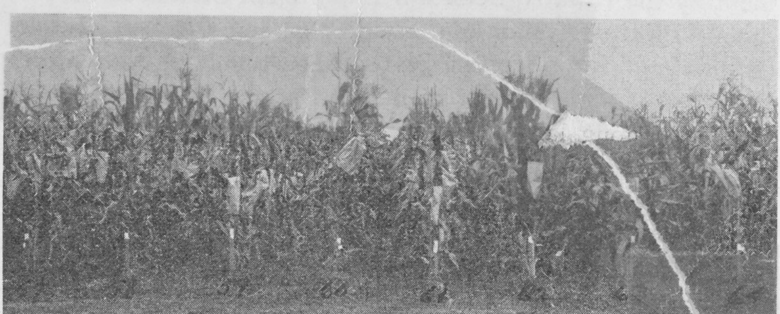

Fig. 1. Good inbred lines differing in plant height, ear height and other characters.

percent of this reduction in vigor occurs in the first five generations of selfing. Inbreeding results in a rapid approach toward plant uniformity within any progeny or line. Differences from line to line, however, often are extreme as illustrated in fig. 1. Practically all of the plants in one line may be strong, erect, disease-resistant, or frost-resistant while a neighboring line may have plants which are spindling, weak-rooted, badly infected with smut or the ear rots, or which are injured by temperatures several degrees above freezing.

REASONS FOR INBREEDING

The chief reason for inbreeding is to obtain pure or true breeding lines, to permit selection of the very best hereditary material in such condition that its performance can be predicted with reasonable certainty. The high degree of uniformity attained among the plants of an inbred line after a few generations of self-pollination is present in the cross between two such lines. The crossed plants all will have the same heredity. If the parents contribute many genes for high yield, every plant will have the same high yielding capacity. If they contribute few genes for vigor and yield, every plant will be lacking in vigor.

Inbreeding brings to light and makes possible the elimination ~~of deleterious~~ or inferior recessive characters, such as white or yellow seedlings which die as soon as the food material stored in the seed is used up, dwarf plants, striped plants and many other less extreme defects. Under natural conditions these characters are suppressed by the constant crossing of corn. As these weaknesses are brought to light by selfing, the lines which possess them are discarded and only the stronger lines are continued. Experimental results indicate that the more vigorous lines tend to produce the outstanding crosses and, from the standpoint of practical production, they certainly are much more desirable. By careful selection among large numbers of progenies it is possible to get reasonably vigorous lines, yielding perhaps one-half as much as the original variety.

TECHNIC OF INBREEDING

Corn is a naturally cross-pollinated plant. It is necessary, therefore, to control pollination artificially to obtain a self-fertilized ear.

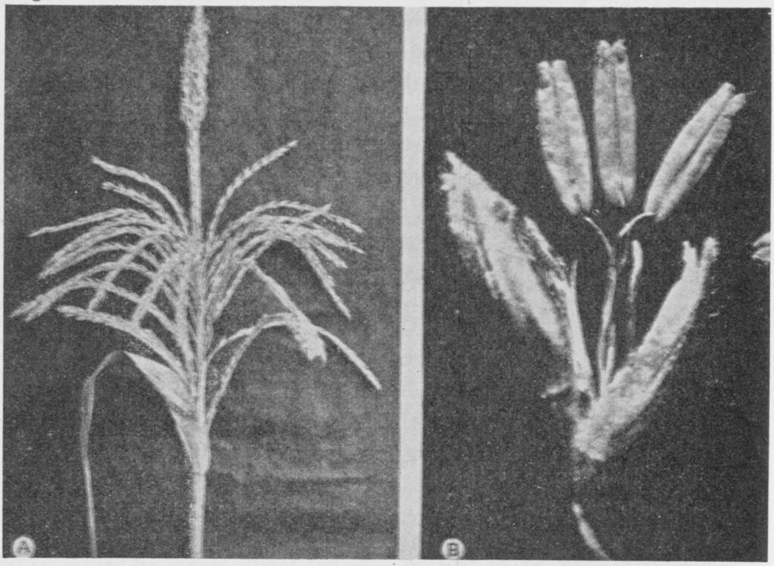

Fig. 2. The staminate or male inflorescense of the corn plant.
A. Complete tassel.
B. Single spikelet showing anthers and pollen. (After Richey.)

The tassel usually appears shortly before the silks on the same plant and soon starts shedding pollen. It sheds pollen for 3 or 4 days, or even longer. Figure 2 shows the appearance of a tassel and of a single spikelet from the tassel when pollen is being produced.

To obtain a self-fertilized ear it is necessary to cover the ear shoot before any silks appear, collect pollen from the tassel and artificially apply it to the silks. A bag, 2½ x 6 inches, made of glassine or semi-transparent paper, is convenient to cover the ear shoot. Such a bag permits observation of the silks as they grow. When the silks have grown out about 2 inches, the bag is removed and the shoot cut back, removing about an inch of the husk tips. Fresh cut silk ends are not receptive to pollen. The sides of the silks are receptive, however, along their entire length, and they must not be exposed below the cut ends nor should pollen be allowed to sift down among them. The bag should be replaced immediately after the silks are cut to prevent later contamination.

The tassel is covered with a large paper bag at the time that the silks are cut back. A 12-pound bag made of heavy Kraft paper, having the seams joined with waterproof glue is satisfactory. Two types of such bags are made, the flat or satchel bottom type and the pointed or square bottom. The square bottom type has proved to be the most satisfactory. A tassel bag in place is shown in fig. 3. It should be left on for about 24 hours and the pollen then collected. Corrugated paper clips may be used conveniently to fasten the tassel bags on the tassel. Edges should be placed together and corners folded over and fastened as tightly around the neck of the tassel as possible. When the tassel bag is removed, care must be taken to avoid spilling the pollen.

Fig. 3. Tassel bagged for collecting pollen.

Pollen should be applied to the silks so as not to expose them to contamination from outside pollen during the operation. A convenient method is as follows: Fold the tassel bag about one-third of the distance from the bottom, holding it so that the pollen will remain in the bottom of the bag. Slip the tassel bag over the shoot to be pollinated, reach up inside the bag and carefully remove the glassine shoot bag without touching or exposing the silks. Pull the tassel bag down carefully with one edge of the bag between the shoot and the stalk.

Either break down the leaf and let the other edge of the

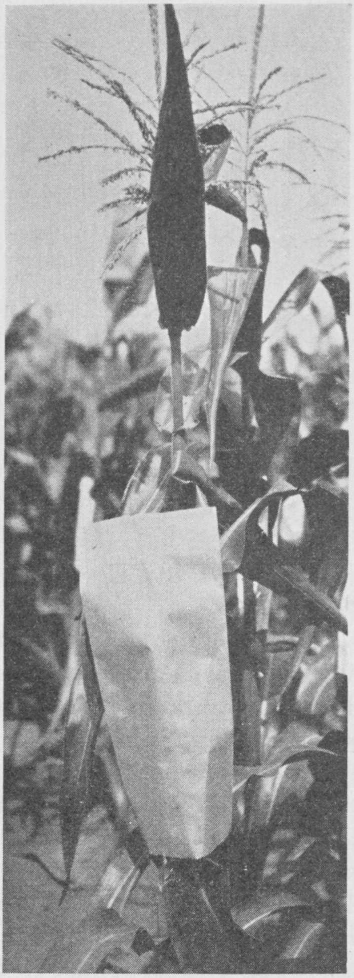

Fig. 4. The completed pollination.

bag remain outside the leaf and shoot, or pull the outside edge of the bag between the shoot and the leaf sheath. Then flip the bottom of the bag upwards, spreading it open as it is lifted, and shake vigorously; this causes the pollen grains to fall upon the silks. Pull the two front edges of the bag around the stalk, fold them twice and fasten with a paper clip, or pull three edges of the bag together and fasten with a clip without folding. This completes the pollination process. A completed pollination is shown in fig. 4.

It is necessary to inspect the bags occasionally to make sure that the ear shoots do not grow through them and expose the silks while they are still receptive. The bag may be left on the ear until harvest.

Another method of making artificial pollinations is known as the "bottle method." The ear shoots are bagged in the same manner as in the previous method. When the silks have appeared and the tassel is shedding pollen, the tassel is cut with about 6 or 8 inches of stalk and placed in a 12-pound bag. The shoot bag is removed, the shoot cut back as explained in the previous method and the large bag with the enclosed tassel placed over the shoot. The end of the tassel stem is placed in a 2-ounce bottle of water that is hung, with a copper wire, on the stalk just above the ear-bearing node. The water keeps the tassel alive until fresh silks grow out to be pollinated. The bag should be fastened around the stalk as in the

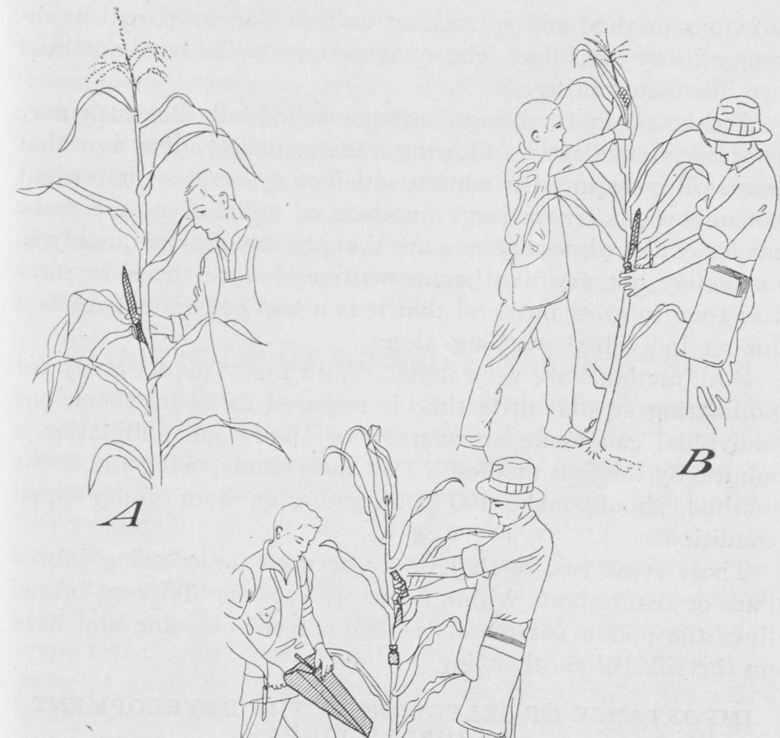

Fig. 5. Steps in the bottle method of inbreeding: A. Ear shoot is covered to exclude foreign pollen; B. Removing tassel and hanging bottle of water on corn plant; C. Placing tassel in paper bag and cutting back ear shoot to prevent contamination while bags are being exchanged; D. Placing bag with enclosed tassel over ear shoot; water keeps tassel shedding pollen until silks grow out again; E. Fastening bag completes the job.

previous method and spread out so that the tassel will be directly above the silks. The various steps in the bottle method are illustrated in fig. 5.

The bottle method is advantageous in that the work may proceed immediately following rain or heavy dew and that less skill is required to obtain satisfactory results—important considerations where large numbers of pollinations are to be made. Chief disadvantages are that the tassels die quickly in extremely hot dry weather, sometimes before the silks have had time to grow out, and that it is a less convenient method for an individual working alone.

Both methods are very rapid. With many plants ready for pollinating so that little time is required to locate them, one individual can make an average of about one pollination a minute by the first method. Two individuals, using the bottle method, should make 100 pollinations an hour under equal conditions.

These same two methods may be used for crossing inbred lines or sister plants within lines. In crossing different inbred lines the pollen (or tassel) is taken from one line and used on the silks of another line.

IMPORTANCE OF SELECTION IN THE DEVELOPMENT OF INBRED LINES

Source of the inbred lines may be either high-yielding, open-pollinated varieties or hybrids. In the Iowa program satisfactory lines have been obtained from the white varieties, Four-County White and Silver King, and from the yellow varieties, Iodent, Lancaster Surecrop, Black Yellow Dent, Proudfit Yellow Dent, Krizer Bros. Yellow Dent, McCulloch Yellow Dent, Osterland Yellow Dent, Clark Yellow Dent, Walden Dent, Golden King, Krug and Steen Yellow Dent. An attempt is now being made to obtain new inbred lines from the better hybrids. This process appears to offer some promise, but few superior lines have as yet been segregated in this way.

The quality ears from the more desirable plants are selected each year for continuation of the inbred lines. Plants are selected on the basis of yield, erectness, maturity, low ears, dark green chlorophyll, good tassels and freedom from suckering, smut, rust, rots, molds, barren plants, broken shanks and abnormalities. Selection is effective only for those characters which are inherited and which may be definitely classified in the line. Selection of lines prepotent for high yield must be based very largely on their performance in crosses.

Experience has shown that the isolation of good inbred lines requires the production and testing of a large number of lines. From 10 to 20 thousand self-pollinations are made at Ames each year. A large proportion of the inbred lines obtained through the inbreeding process are only average or mediocre. It is necessary to test many strains, therefore, to find the occasional desirable one.

UTILIZATION OF INBRED LINES IN HYBRIDS

All inbred lines of field corn so far developed are inferior to open-pollinated varieties in vigor and yield. Until such time as decidedly more productive lines are developed, the ultimate use of inbred lines in commercial corn growing is in the production of hybrids. The better hybrid combinations among selected lines have given substantial increases in yield over the better open-pollinated varieties now grown. Other desirable characteristics, such as strength of stalks and of roots and freedom from specific diseases are advantages which *some* of these hybrids possess. Not all hybrids are worth while; some hybrids are much less desirable than the average open-pollinated corn. To produce a satisfactory hybrid the corn breeder must test a large number of crosses between his outstanding inbred lines. When a desirable combination is found, it can be expected to perform in the same way each time it is produced.

KINDS OF HYBRIDS

Several kinds of hybrids are possible, depending upon the number of inbred lines involved. The simplest hybrid, known as a single cross, is made by crossing two inbred lines. A cross between a single cross and an inbred line is known as a three-way cross. A cross between two single crosses is called a double cross, while two double crosses combined may be termed a double-double or a multiple cross. The product resulting from combining many inbred lines may be referred to as a synthetic variety. A top cross is a cross between an inbred line and an open-pollinated strain.

Each of these various types of hybrids has its use. The method of producing single and double crosses is illustrated diagrammatically in fig. 6. Most investigators in corn breeding agree that, with present inbred lines, the double cross is the most economically produced field corn hybrid.

The single cross, used extensively for sweet corn production where uniformity is of extreme importance, has been suggested frequently for commercial planting. High cost of seed is the principal objection to single crosses for field corn production. Single-crossed seed, of necessity, is produced on inbred plants, relatively poor producers, both of seed and pollen. The seasons of 1934 and 1936 demonstrated that inbred plants cannot stand adverse conditions as well as single-crossed plants. This makes the cost of producing single-crossed seed relatively great, because the acre yield of seed is small. When the single-crossed seed is used only as a parent stock for making double-crossed seed, however, the quantity needed is small, and its high cost is relatively unimportant.

Seed of three-way crosses is less expensive to produce than that of single crosses but more expensive than that of double crosses. In most cases they are produced where three lines are available which combine well, but a suitable fourth line is lacking. As the supply of desirable lines increases, three-way crosses may be entirely replaced by double crosses.

Double-crossed seed is produced on single-crossed plants, which are highly productive of quality seed. Single-crossed plants, likewise, produce pollen abundantly. This makes possible a greater proportion of seed-producing rows to pollen rows in the crossing plot. Furthermore, single-crossed plants withstand adverse conditions much better than inbred plants, reducing the risk in seed production. All of these factors have an important bearing on the cost of producing seed and favor the use of double crosses.

TECHNIC OF CROSSING

Crosses may be made by hand-pollination or by growing the strains to be crossed in alternate blocks in an isolated plot and detasseling, before they have shed any pollen, all of the plants of the strain on which seed is to be produced. Experimental hybrids requiring only small quantities of seed are best made by hand-pollination. The production of large quantities of hybrid seed is accomplished less expensively in isolated crossing plots than by hand-pollination (fig. 7). In these cross-

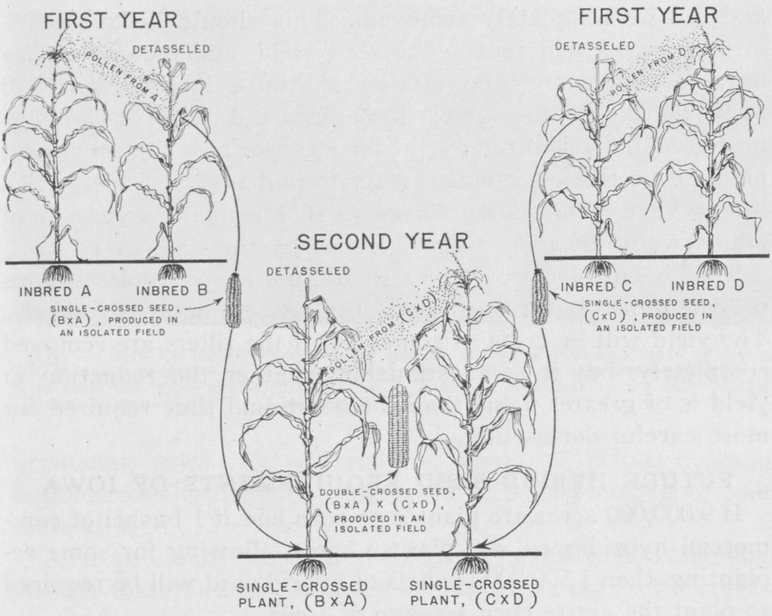

Fig. 6. Method of producing seed of single and double crosses.

ing plots the parent which furnishes the pollen is called the male or pollen parent and the one detasseled is called the female or seed parent. A desirable practice in labeling crosses is to indicate the ear-producing parent first. For example, L289 x I205 indicates that L289 was used as the ear-producing parent and I205 as the pollinator.

The ratio of male to female rows depends upon the kind of cross to be made and the abundance of pollen produced by the male parent. Inbred lines lack vigor and pollen producing ability. When they are used to supply the pollen, it is safest to plant one row of male parent to every two rows of female parent. When single-crossed plants supply the pollen, one row of male parent to four rows of female parent is satisfactory.

Tassels must be removed from the female rows before they have shed any pollen. Pulling, usually as soon as they are well out of the "boot," is the most satisfactory method of removal. This probably will be 1 or 2 days after they are first visible. If the pulling is done too soon, one or two leaves may be removed with the tassel, or the tassel may break off and not be completely removed. This should be avoided—loss of leaves will reduce the seed yield, and incomplete removal of the tassel necessitates additional labor. When 90 to 95 percent of the tassels have been pulled, it probably is more economical to remove at once those from the remaining plants even though it is necessary to pull several leaves. The loss in yield from pulling leaves on such a small percentage of plants would be more than balanced by the time saved.

Tassels on tillers or suckers should not be overlooked. Tops may be pulled out, regardless of the loss of one or two leaves. The yield will be reduced somewhat if the tillers are removed completely, but it is questionable whether the reduction in yield is of greater value than the additional time required for more careful detasseling.

FUTURE HYBRID SEED REQUIREMENTS OF IOWA

If 9,000,000 acres are planted to corn and if 1 bushel of commercial hybrid seed will plant 6 acres, allowing for some replanting, then 1,500,000 bushels of hybrid seed will be required to plant the entire corn acreage of Iowa.

An average acre yield of 30 bushels of commercial hybrid seed may be reasonably expected in producing double-crossed seed with a ratio of one pollen-producing row to four seed-

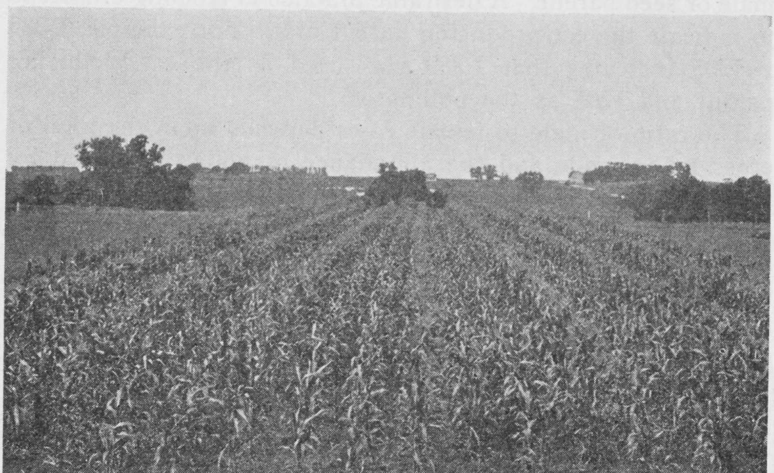

Fig. 7 (A). Producing single-crossed seed on detasseled plants in two-row blocks. The plants were grown from inbred seed produced by open-pollination in isolated plots such as are shown in fig. 8.

Fig. 7 (B). Producing double-crossed seed on detasseled plants in four-row blocks. The plants were grown from single-crossed seed produced on detasseled plants in isolated plots like those shown in fig. 7 (A). Note the difference in the ratio of male and female rows in fig. 7 (A) and fig. 7 (B).

producing rows. It will require, therefore, 50,000 acres of double-crossing fields to produce the 1,500,000 bushels of commercial seed.

Seed produced on inbred plants generally is somewhat smaller than the seed produced on hybrid plants. As the single-crossed seed for planting the 50,000 acres is produced on inbred plants, 1 bushel will plant at least 7 acres. About 7,143 bushels of single-crossed seed, therefore, will be needed.

Production of single-crossed seed is somewhat more hazardous than the production of double-crossed seed. Unfavorable conditions are likely to reduce the yield of inbred plants much more than that of hybrid plants. With a ratio of 1 row of pollen-producing parent to 2 rows of seed-producing

Fig. 8. Increasing the seed of an inbred line by open-pollination in an isolated field. The plants were grown from hand-pollinated seed. A distance of 70 to 80 rods from other corn is highly desirable.

parent, an acre yield of 7 bushels of single-crossed seed is a reasonable probability. To produce the necessary seed, therefore, will require about 1,020 acres of single-crossing fields.

About 146 bushels of inbred seed will be needed for planting the 1,020 acres of single-crossing fields. About 14 acres in isolated fields (fig. 8) will be required to produce this inbred seed. Two bushels of inbred seed will be needed to plant the 14 acres. Hand-pollinated seed is highly desirable for this purpose. Two bushels of seed should be produced on 2,000 hand-pollinated ears. Plants for this purpose may be grown on about 1/4 acre.

These requirements are summarized in table 1. Figures in this table should be considered only as estimates. Inbred lines as well as single crosses vary in their productivity, and seed yield will vary with seasonal conditions. It probably will be highly desirable to hold over from year to year surplus seed of the inbred lines and single crosses. Attempting to just supply the demand for commercial seed certainly will result in a shortage in unfavorable years. Two-year old seed, if properly handled, generally is entirely satisfactory for planting.

NEW HYBRIDS MUST BE TESTED

The hundreds of crosses made by the Experiment Station must be compared carefully before they can be recommended for general growing. Experience has shown that some hybrids may yield twice as much as others grown under the same conditions.

Under the system of testing used at the Iowa Station new inbred lines have been tested first in top crosses with an open-pollinated variety. This is an inexpensive way of obtaining reliable results on a large number of lines and permits each line to be tested annually, through several years, thus providing for a determination of the seasonal effect. The lines are crossed with an open-pollinated variety in a detasseled crossing plot in which the variety is used as the pollinating parent. Early maturing inbred lines have been crossed with Golden King, an early variety. Later lines have been crossed with Krug, a rather late variety. Fifty percent or more of the inbred lines may be discarded on the basis of 2 or 3 years' results from this preliminary test. Remaining lines are given

TABLE 1. ESTIMATED ACREAGES AND YIELDS OF INBRED LINES AND SINGLE CROSSES NECESSARY TO PRODUCE THE DOUBLE-CROSSED SEED REQUIRED TO PLANT THE NORMAL CORN ACREAGE OF IOWA.

Kind of plot	Acres	Estimated Yields	
		Acre (bu.)	Total (bu.)
Hand-pollination (for increasing inbred lines)	¼	8	2[1]
Isolated increase (for increasing inbred lines by open-pollination)	14	10+	146[1]
Single-crossing	1,020	7	7,143[1]
Double-crossing	50,000	30	1,500,000[2]

[1] Estimated on the basis that a bushel will plant 7 acres.
[2] Estimated on the basis that a bushel will plant 6 acres.

a more careful test in combination with each other. Essentially, the first comparisons in top crosses are to find which inbred lines possess the most promising heredity, and the later comparisons in double crosses are to discover the particular combinations giving the best results in field planting.

Double crosses between the lines which have proved the most promising in the tests of top crosses are compared first at the Experiment Station. Outstanding combinations then are entered in the Iowa Corn Yield Test and finally compared by farmers. In these comparisons the characters given consideration are yield, lodging, disease, ear drop, maturity, ear size, shelling percentage and quality.

Hybrids differ markedly in their ability to withstand storms (fig. 9). Some hybrids lodge badly in a severe windstorm, while others in neighboring rows continue to stand almost perfectly. Some hybrids lodge because of weak stalks and others because of weak roots. Little lodging occurs in some seasons, and under such conditions it is not possible to recognize lodge resistant strains. Devices have been developed and used at the Experiment Station for testing the breaking strength of the stalk and the pulling resistance of the roots. These devices furnish a means of testing the hybrids independently of storms, thus materially speeding up the process of selection.

IOWA HYBRIDS IN COMMERCIAL PRODUCTION

When a hybrid has been tested and its desirability ascertained, seed of the two foundation hybrids is increased by the Experiment Station and offered for sale to individuals or organizations desiring to undertake production of the final or commercial double-crossed seed. Seed of the parent inbred

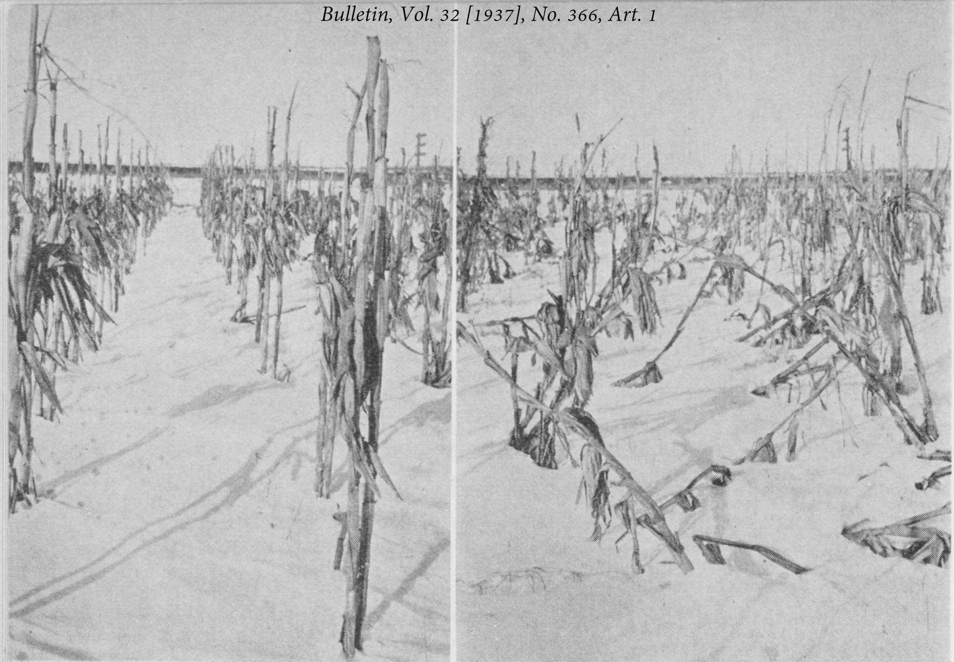

Fig. 9. Hybrids differ markedly in strength of stalks and roots. These pictures of two hybrids growing in the same field were taken on the same day.

lines is increased and likewise offered for sale to private growers. When another station wishes to release a desirable hybrid involving one or more Iowa lines, the Iowa Station will release the Iowa lines involved. The Station expects the buyers of this seed to maintain each line under its original name, number or other designation.

HYBRIDS DEVELOPED AND RELEASED BY THE IOWA STATION

Seed of four double crosses developed by the Iowa Agricultural Experiment Station in cooperation with the Bureau of Plant Industry, United States Department of Agriculture, is now commercially available to Iowa farmers. These crosses, known as *Iowa Hybrids* 931, 939, 942 and 13, all have yellow endosperm color. They lodge less and yield considerably more than the standard open-pollinated varieties of similar seasonal requirements. Chief difference among them is the time they require to reach maturity. Seed of the single-crossed parent stocks for making *Iowa Hybrids* 931 and 942 was first made available to growers in 1932. The other two hybrids were distributed in the spring of 1934. The six inbred lines involved in the *Iowa Hybrids* 931, 939 and 942 were first released to private growers in the spring of 1934. The four inbred lines in Iowa Hybrid 13 were released in 1935. Only a small quantity of seed of each inbred line was sold to any one individual.

Description of the Released Station Hybrids

Iowa Hybrid 931 [(L 289 x Cl 447) x (Os 420 x Os 426)] is the earliest maturing of the four hybrids distributed by the Station. The parent single cross, Os 420 x Os 426, has rather attractive ears, somewhat of the old show type. Kernels are fairly large and deep, distinctly reddish-yellow color, making the seed noticeably different from that of most yellow corn and for this reason this single cross is frequently used for the female parent in producing the double-crossed seed. It tillers profusely under some conditions, a serious objection to its use as a female parent because of the increased work of detasseling, but a desirable characteristic where it is used as a male parent. The parent single cross, L 289 x Cl 447, is earlier than Os 420 x Os 426, is relatively free from tillering, produces quality seed and is the recommended cross to be used as the seed-producing parent.

It is doubtful whether Iowa Hybrid 931 is early enough to be grown with safety in the extreme northern tier of Iowa counties, particularly in the eastern half of the state. It is most satisfactory in the second tier of counties. Compared for 5 years in the Northern Section of the Iowa Corn Yield Test[4], this hybrid yielded an average of 9.2 bushels more per acre and in every comparison had less lodging than the open-pollinated varieties (table 2). In 24 comparisons made by growers on their own farms during the 6-year period, 1930-35, 19 growers preferred Iowa Hybrid 931 to the home variety.[5] While it is not normally a full season corn at Ames, it has consistently outyielded varieties of comparable maturity for 3 years and also has had a higher percentage of erect plants (table 2). It drops a higher percentage of ears before harvest than the average of the open-pollinated varieties (table 2).

Iowa Hybrid 942 [(Os 420 x Os 426) x (L 289 x I 234)] is perhaps better known in Iowa than any of the other Station hybrids. Three of the four inbred lines which constitute its

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[4] The data in the Iowa Corn Yield Test were obtained by Joe L. Robinson, research associate professor of farm crops, A. A. Bryan and M. M. Rhoades.

[5] Reports from farmers' trials were furnished by Joe L. Robinson.

parentage also are used as parents of Iowa Hybrid 931. The single cross Os 420 x Os 426 generally is used as the seed parent in producing this double cross. The single cross L 289 x I 234 is perhaps 20 percent higher yielding than Os 420 x Os 426, is free from tillers and produces seed of only fair quality, being somewhat subject to silk rot or silk cut and under some conditions has more moldy seed than Os 420 x Os 426. Kernels are deep and more or less starchy under some conditions. Iowa Hybrid 942 is slightly later in maturity than 931, being well adapted to the North Central Section. Five years' results from the Iowa Corn Yield Test in the North Central Section show this hybrid yielded 6.7 bushels per acre more than the average of the open-pollinated strains with which it was compared (table 2).

It has been superior to the average open-pollinated strains in the South Central Section in yield, maturity and lodging resistance. In every comparison it lodged less than the open-pollinated strains, although this advantage has not been as

TABLE 2. SUMMARY OF THE DATA FROM LOCAL TESTS (AMES) AND FROM THE IOWA CORN YIELD TEST COMPARING *IOWA HYBRIDS* 931, 939, 942 AND 13 WITH OPEN-POLLINATED VARIETIES AND WITH OTHER HYBRIDS DURING THE 5-YEAR PERIOD, 1932-36.

Variety or Hybrid	Acre yield bu.	Moist percent	Lodging grade[1]	Damaged kernels percent[2]	Dropped ears percent
Tests at Ames					
Early Group					
Golden King	40.5	14.8	2.8	2.8	1.1
Iowa Hybrid 931	55.7	18.1	1.9	4.0	4.2
Midseason Group					
Steen Yellow Dent	50.7	19.4	2.5	6.4	3.3
Osterland Yellow Dent	49.1	17.8	2.7	5.7	1.6
Iowa Hybrid 939	64.0	18.5	1.4	5.7	3.3
Iowa Hybrid 942	61.5	17.6	1.8	4.6	4.5
Late Group					
Krug	57.9	21.2	3.3	5.2	2.3
McCulloch Yellow Dent	53.9	20.8	3.5	7.3	3.5
Iowa Hybrid 13	72.5	19.9	2.7	6.7	2.6
Iowa Corn Yield Test					
Northern Section					2
Average of varieties	61.4	21.9	2.8	4.0	2.9
Average of regular hybrids	68.1	21.8	2.1	4.3	3.3
Iowa Hybrid 931	70.6	22.0	2.1	2.3	9.5
North Central Section					
Average of varieties	57.6	21.5	2.5	2.5	1.5
Average of regular hybrids	62.4	21.8	2.1	3.3	1.9
Iowa Hybrid 939	66.6	21.8	1.7	.8	3.8
Iowa Hybrid 942	64.3	20.8	2.0	1.3	4.3
South Central Section					
Average of varieties	54.3	20.7	2.8	2.6	1.6
Average of regular hybrids	60.5	20.1	2.2	2.8	1.1
Iowa Hybrid 942	59.8	17.9	2.3	2.7	2.5
Iowa Hybrid 939	60.8	19.0	2.0	1.7	2.4
Iowa Hybrid 13	68.0	20.4	2.4	2.2	1.7
Southern Section					
Average of varieties	50.4	20.3	2.8	2.6	1.2
Average of regular hybrids	55.9	19.6	2.2	3.3	1.0
Iowa Hybrid 13	62.4	19.7	2.3	2.9	1.2

[1] The smaller grade indicates the least lodging.
[2] Two-year average, 1935-36.

marked as with some other hybrids. In 70 comparisons on Iowa farms during a 6-year period, 62 growers preferred Iowa Hybrid 942 to the varieties with which it was compared. During 5 years' tests at the Experiment Station this hybrid yielded 10.8 bushels more per acre than the highest yielding open-pollinated varieties with which it was compared. Its lodging resistance has been greater than that of the most nearly erect open-pollinated variety in these tests (table 2).

Iowa Hybrid 939 [(Os 420 x Os 426) x (L 289 x I 205)] was not released for commercial production until 1934. Only one line of this hybrid differs from that of Iowa Hybrid 942, I 205 being substituted for the I 234 of 942. It has the same general adaptation as 942, and in 34 tests extending over the 5-year period, 1930-34, these two hybrids yielded similarly.

Results obtained in 1935 were much more favorable to Iowa Hybrid 939, it having a small, but significant advantage in yield, in ability to resist lodging and to hold ears (table 2). Iowa Hybrid 942 had a little less moisture at harvest than 939. Fifteen of the seventeen growers comparing Iowa Hybrid 939 with their own corn preferred 939.

Iowa Hybrid 13 [(Bl 349 x L 317) x (Bl 345 x Mc 401)] is adapted to the southern half of the state. Foundation single crosses were first distributed for the commercial production of this hybrid in the spring of 1934. Single cross Bl 349 x L 317 is recommended as the seed parent and Bl 345 x Mc 401 as the pollen parent. This hybrid yielded 13.7 bushels per acre more than the average of the open-pollinated varieties in the South Central Section of the Iowa Corn Yield Test for 5 years (table 2). In these tests it had materially less lodging than the open-pollinated strains.

Seventeen of twenty farmers preferred Iowa Hybrid 13 to the home variety, although only 10 of them reported that it stood up better. It tillers rather profusely, and the tillers tend to fall over as the corn reaches maturity. In 5 years' trials at the Experiment Station it averaged 14.6 bushels per acre more than the highest yielding open-pollinated variety and was superior to the most nearly erect open-pollinated variety in lodging resistance.

Iowa Hybrid 13 seems to be more drouth and heat resistant than the average, being one of the best in this respect in trials at the Station in 1934. Farmers who grew it in the southern Iowa area of extreme drouth that year reported that it stayed green longer than any other corn. It made the same record in farmers' trials again in 1936. Under some conditions it has shown considerable susceptibility to ear rots.

Description of the Released Inbred Lines

The Experiment Station has officially released the 10 inbred lines involved in the four *Iowa Hybrids* now in commercial production. A brief description of each released line is given in table 3 and on the following pages. Pictures of a typical plant and of typical ears and kernels of each line are shown in figs. 10-29.

These descriptions must be taken as approximate and not absolute. Most of the characters described are more or less variable from season to season and some of them within the season. None of the lines is entirely uniform in number of kernel rows on the ears; some lines are much more nearly uniform than others. Figures given will include most of the ears but an occasional ear may be found beyond these limits. Measurements of ear length and diameter are based on too few ears to be very accurate but give a picture of ear size and shape.

All characters of the lines must be taken into consideration in attempting to identify them from the description in table 3. Lines which are very similar in some characters may differ very definitely and consistently in one or two other characters.

The following paragraphs give general information on the 10 released lines and on the best methods of using them in the production of the *Iowa Hybrids*. The complete pedigree of each line at the time of its first distribution is included as a matter of record.

I 205

Pedigree: I 205-5-4-2-3-1-1-1-2-2.

Origin: Iodent, a strain of Reid Yellow Dent selected by L. C. Burnett of the Iowa Agricultural Experiment Station.

Characteristics: Transmits to its crosses high yield, resistance to lodging, to chinch bug injury and to smut, and the ability to hold the ears. Ears are susceptible to molds and should be harvested early to avoid damage. It is preferably used as the male parent in crossing with L 289 because it produces more pollen than L 289 and produces poorer quality seed. It also generally synchronizes better with L 289 as to pollen shedding and silking when used as male parent.

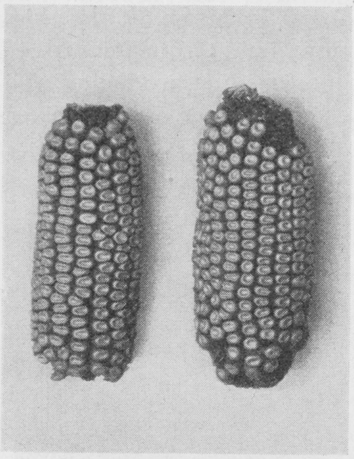

Fig. 10. Typical ears of I 205.

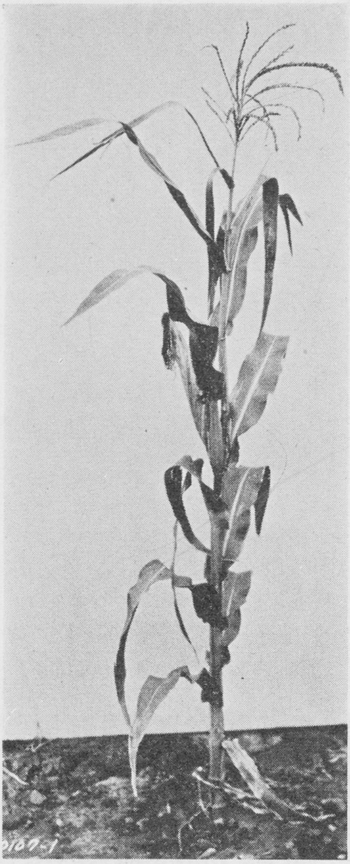

Fig. 11. Typical plant of I 205.

Fig. 12. Typical plant of L 289.

L 289

Pedigree: L 289-4-3-5-2-4-1-1-3-3.

Origin: Lancaster Surecrop, a strain of corn developed by Isaac Hirshey of Lancaster County, Pa.

Characteristics: Plants make rapid, vigorous development throughout the growth period. Susceptible to stalk smut and to diplodia stalk rot, plants sometimes break badly after maturity. This line usually produces a high yield of quality seed. It is preferably used as seed parent in making single crosses because of the high production and quality of seed, its poor pollen-producing ability and its few or no suckers to detassel.

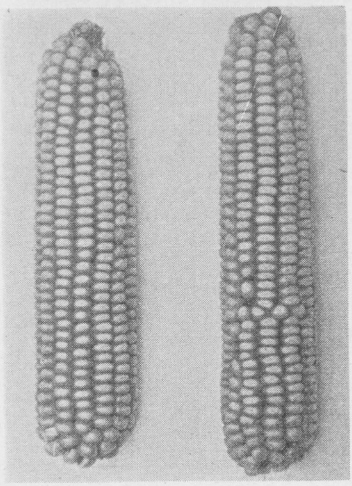

Fig. 13. Typical ears of L 289.

I 234

Pedigree: I 234-2-3-1-4-1-3-2-3-1.

Origin: Iodent.

Characteristics: This line contributes to its crosses yield, rapid drying of the grain and freedom from smut. Kernels shatter badly from the inbred ears and also from the ears of the single cross with L 289, making the use of this single cross as a seed parent objectionable. This line is very sensitive to unfavorable early growing conditions but withstands drouth and heat and usually produces abundant pollen. The I 234 usually is preferable as pollen parent in crossing with L 289 although it synchronizes well with L 289 as either pollen or seed parent and the seed yields of the two lines are about equal.

Fig. 15. Typical plant of I 234.

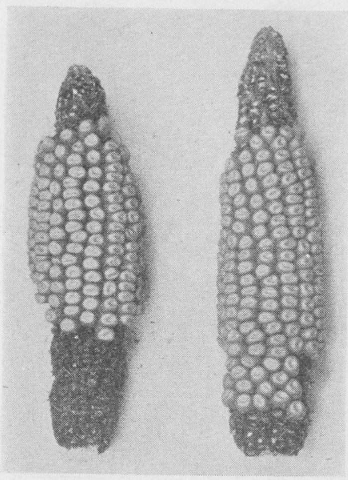

Fig. 14. Typical ears of I 234.

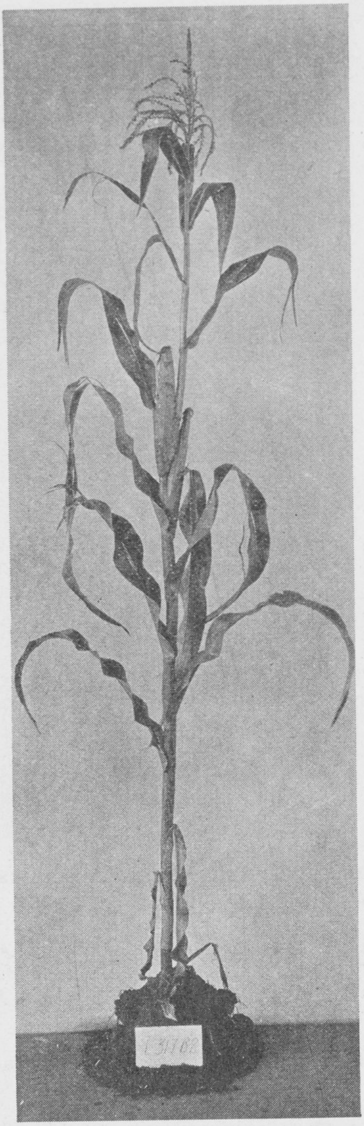

Fig. 16. Typical plant of L 317.

L 317

Pedigree: L 317-3-1-2-5-4-2-1-3-3-3.

Origin: Lancaster Surecrop.

Characteristics: A late line with dark green chlorophyll. It exhibits marked resistance to wilting and firing, although both pollen and seed production are adversely affected by drouth and heat. Its crosses perform unusually well under such conditions and seem to have a wide range of adaptation. It is preferably used as pollen parent in crossing with B1 349 because it is later and usually produces more pollen but less seed than B1 349. If used as seed parent, it should be planted a few days earlier than B1 349.

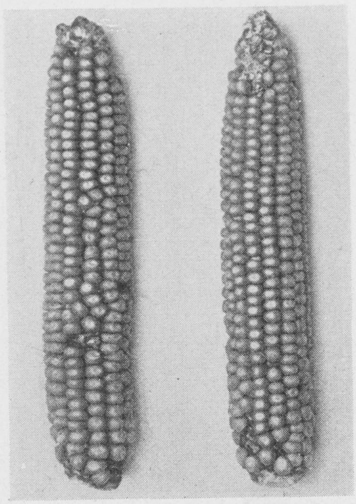

Fig. 17. Typical ears of L 317.

Mc 401

Pedigree: Mc 401-1-2-5-2-1-1-1-1-1.

Origin: McCulloch Yellow Dent, a strain developed by Fred McCulloch of Poweshiek County, Iowa, and ranking above the average in the Iowa Corn Yield Test through a 16-year period.

Characteristics: This line produces an unusually large number of suckers, is resistant to drouth and is an excellent pollen producer. The ears are susceptible to the ear rots under certain conditions. It synchronizes well with B1 345 in pollen shedding and silking. Mc 401 is preferably used as the pollen parent in crossing with B1 345 because of its heavy suckering tendency, its production of pollen, and its usually poor seed quality.

Fig. 19. Typical ears of Mc 401.

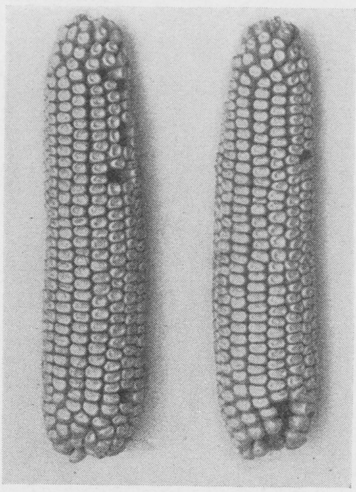

Fig. 18. Typical plant of Mc 401.

Fig. 20. Typical plant of B1 345.

B1 345

Pedigree: B1 345-4-1-6-2-R-3-2-2-1.

Origin: Black Yellow Dent, a strain developed by Clyde Black in Dallas County, Iowa, and ranking above the average of the varieties in the Iowa Corn Yield Test through a 16-year period.

Characteristics: This is a very weak-rooted line, a condition accentuated where grown following corn. It also is susceptible to stalk rot. To prevent loss from these troubles the seed should be harvested early. The line may be used as either pollen or seed parent in making the single cross with Mc 401, but generally is preferable as seed parent because it produces only about one-half as many suckers as Mc 401, is equal to Mc 401 in seed production and produces pollen less abundantly than Mc 401.

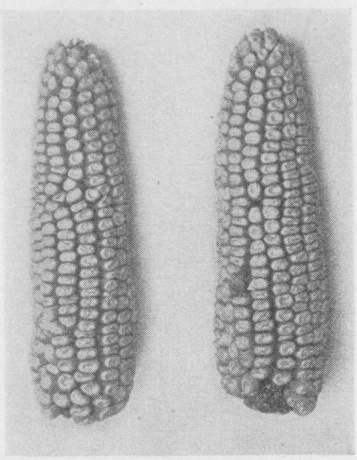

Fig. 21. Typical ears of B1 345.

B1 349

Pedigree: B1 349-5-1-4-1-4-2-1-1-1.

Origin: Black Yellow Dent.

Characteristics: The upper two or three leaves of the plants of this line are very susceptible to firing, but the tassels do not burn except under extreme heat and drouth. This line should be used as seed parent in making the single cross with L 317 because it is earlier and would need to be planted later if used as pollen parent. It is susceptible to ear smut, but generally the percentage of infected ears is small. Although tests in top crosses with Krug conducted over a wide area indicate this line does not have a wide range of adaptation, Iowa Hybrid 13, in which it is involved, is especially widely adapted.

Fig. 22. Typical plant of B1 349.

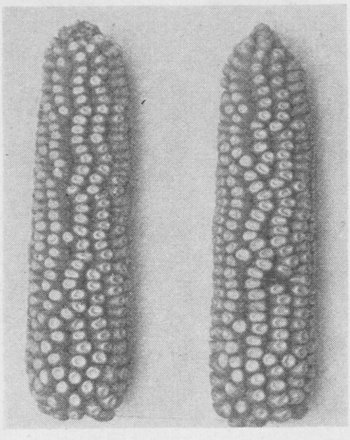

Fig. 23. Typical ears of B1 349.

Fig. 24. Typical plant of Os 426.

Os 426

Pedigree: Os 426-5-2-4-4-2-4-1-3-3-1.

Origin: Osterland Yellow Dent.

Characteristics: This line produces quality seed, and the seeds are somewhat smaller than those of Os 420. These characteristics are favorable to its use as seed parent in crossing with Os 420. It suckers rather profusely, however, and is later in tasseling and silking than Os 420. It is preferable to use Os 426 as male parent and Os 420 as seed parent.

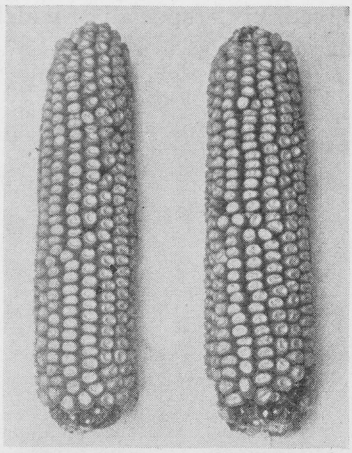

Fig. 25. Typical ears of Os 426.

Os 420

Pedigree: Os 420-2-7-6-4-2-3-2-1-1.

Origin: Osterland Yellow Dent, a strain of Reid Yellow Dent developed by H. F. Osterland of Franklin County, Iowa, and ranking above the average in the Iowa Corn Yield Test through a 16-year period.

Characteristics: This line is relatively early in silking, but the ears dry slowly after maturity, resulting in a relatively high moisture content at harvest. It usually has been used as seed parent in the cross with Os 426 because it is earlier in silking, produces few or no suckers and generally produces less pollen than Os 426. If used as pollen parent, it probably would be desirable to plant at least one-half of the rows a few days later than the Os 426. It is susceptible to diplodia stalk rot which occasionally causes stalk breaking after maturity, making early harvest of seed desirable.

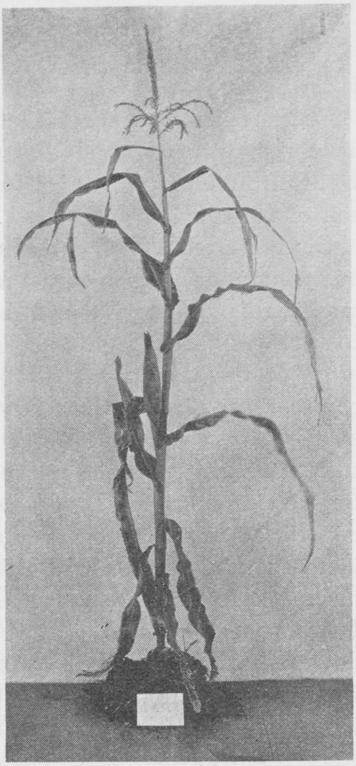

Fig. 27. Typical plant of Os 420.

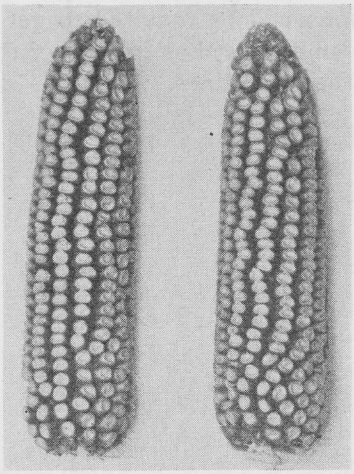

Fig. 26. Typical ears of Os 420.

C1 447

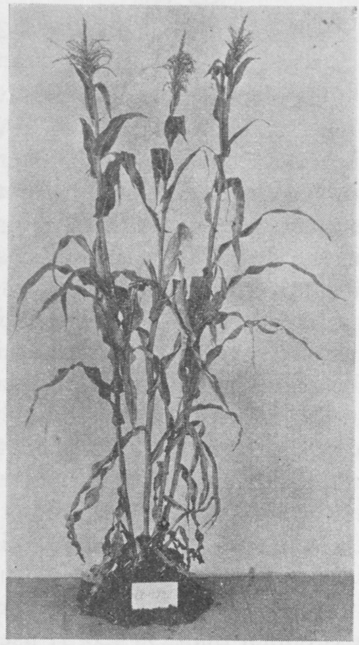

Fig. 29. Typical plant of C1 447.

Pedigree: C1 447-5-1-8-5-3-3-1-2-3-1.

Origin: Clark Yellow Dent, an early strain of Reid Yellow Dent obtained from James Jensen of Newell, Iowa.

Characteristics: This line has a compact, much-branched tassel which is very susceptible to firing. Often one-half or more of the tassels are almost completely dead when they emerge from the "boot." Despite this undesirable characteristic it pollinates L 289 satisfactorily and a much greater yield of seed is obtained than if the cross is made using C1 447 as seed parent. C1 447 flowers earlier than L 289 and should be planted about 7 to 10 days later. It is not a highly productive line, and perhaps twice as many hand-pollinations will be required to get a pound of seed as for any of the other nine lines.

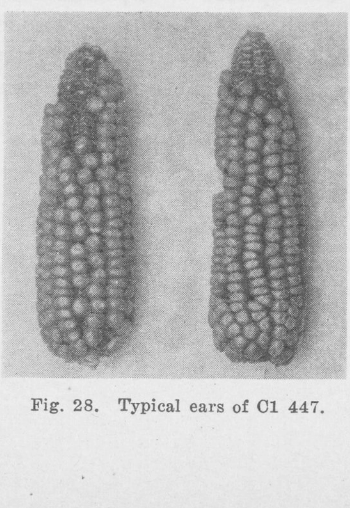

Fig. 28. Typical ears of C1 447.

TABLE 3. DESCRIPTION OF INBRED LINES OF CORN USED AS THE PARENTS OF *IOWA HYBRIDS* 931, 939, 942 AND 13 AND OFFICIALLY RELEASED BY THE EXPERIMENT STATION FOR COMMERCIAL SEED PRODUCTION.

Character	I 205	I 234	L 289	L 317	B1 345
Flower parts:					
Silk color	green	bright red	green tinged with red	green	green
Anther color	pink	bright red	pink	dull red	red turning to brown
Glume color	slightly red	slightly red	slightly red	slightly red	slightly red
Tassel:					
Number of branches	15-20	10-20	15-25	20	10-20
Form	drooping	upright central spike, horizontal branches	drooping	drooping	erect, compact
Pollen shedding	medium	good	poor	good	medium
Plant:					
Height (ft.)	5½-6	6½-7	6½-7	6½-7	5¾-6¼
Nodes above ground:					
To ear	8-9	8-9	8	10	10
Total	13-14	14	13	15	17
Ear height (in.)	26	33	30	40	31
Tillers	none	many	none	few	many
Stalk strength	strong	medium, flexible	medium	medium	weak
Root system	strong	strong	strong	medium	very weak
Chlorophyll	bluish green	green	green	dark green	light green
Leaves	creased lengthwise	smooth	crinkled	smooth	upper leaves short, erect
Ear:					
Length	short	medium	long	long	medium
Diameter	large	medium	small	small	medium
Kernel row no.	16-18	16-18	10-14	12-16	16-18
Space between kernel rows	narrow	medium	medium	medium	narrow
Kernel row regularity	irregular	irregular	straight	straight	irregular
Kernel color	orange yellow	orange yellow	brownish yellow	orange buff	orange yellow
Kernel indentation	medium	medium	smooth	very smooth	rough
Kernel size	medium	medium	medium	very small	medium
Kernel quality	slightly starchy	slightly starchy	flinty	flinty	rather starchy
Shank strength	strong	weak	weak	medium	medium
Disease resistance:					
Stalk rots	high	medium	low	low	low
Ear rots	medium	medium	high	medium	low
Smut	high	high	low	medium	high
Rust	high	high	high	low	high
Maturity	midseason	midseason	midseason	very late	late

259

TABLE 3—Continued

Character	B1 349	Mc 401	Os 420	Os 426	C1 447
Flower parts:					
Silk color	green	green	green	green	green
Anther color	green	light pink	pink	dark pink	green
Glume color	slightly red	slightly red	slightly red	dark red	slightly red
Tassel:					
Number of branches	8-10	20-30	8-11	8-11	50-70
Form	drooping	slightly drooping	stiff, horizontal branches	stiff, erect	erect, very compact
Pollen shedding	medium	excellent	medium	medium	medium
Plant:					
Height (ft.)	5¾-6¼	6-6½	6-6½	6¼-6¾	5¼-5¾
Nodes above ground:					
To ear	8	8-9	7	8	8
Total	15	14-15	13	13	13-14
Ear height (in.)	27	30	24	27	27
Tillers	many	very many	very few	many	many
Stalk strength	strong	strong	strong	strong	strong
Root system	medium	medium	strong	medium	strong
Chlorophyll	green	light green	light green	green	green
Leaves	smooth, top leaves very susceptible to firing	smooth	smooth	slightly crinkled	unusually wavy margins
Ear:					
Length	medium	medium	medium	medium	short
Diameter	medium	medium	large	medium	small
Kernel row no.	12-14	14-18	14-16	14-16	12-16
Space between kernel rows	wide	narrow	medium	medium	medium
Kernel row regularity	winding	straight	straight	irregular	irregular
Kernel color	dark orange yellow	light orange yellow	brownish red with yellow caps	orange yellow	brownish yellow
Kernel indentation	medium	rough	rough	rough	very smooth
Kernel size	medium	medium	large, thick	medium	very small
Kernel quality	medium flinty	starchy	horny starch	horny starch	flinty
Shank strength	medium	medium	strong	medium	medium
Disease resistance:					
Stalk rots	medium	high	medium	medium	medium
Ear rots	low	medium	high	medium	medium
Smut	very low	medium	high	low	medium
Rust	high	high	high	high	high
Maturity	late	late	midseason	midseason	midseason

260

The kernels of the 10 released lines vary considerably in size, shape and color (fig. 30). The heaviest kernels are those of Os 420. They are unusually thick and often will have fewer kernels to the pound than open-pollinated Reid Yellow Dent. Kernels of L 317 are the smallest, averaging about one and one-half times as many to the pound as those of Os 420. Kernels of Cl 447 also are unusually small. One who is familiar with the lines can identify, with considerable certainty, bulk lots of normally developed kernels.

SEED DISTRIBUTIONS BY THE EXPERIMENT STATION

To insure that the better hybrids developed in the breeding program get into commercial production in Iowa, the Experiment Station has produced, for sale to Iowa producers, small quantities of seed of the parent inbred lines and single crosses. The conditions under which this seed is sold are cutlined below. Inquiries regarding the purchase of it should be addressed to Joe L. Robinson, Agronomy Department, Iowa State College, Ames, Iowa.

Sale of Single-Crossed Seed

It is the policy of the Experiment Station to sell seed of only such foundation single crosses in its possession as enter into the released *Iowa Hybrids.* As each *Iowa Hybrid* becomes established, it is the policy to leave the production of the foundation single crosses to private growers, restricting the Station's efforts to the maintenance of pure stocks of seed of the parent inbred lines. Conditions under which single-crossed seed will be sold may differ from year to year, depending upon the available supply.

Sale of Seed of Released Inbred Lines

Limited quantities of seed of pure stocks of the 10 released inbred lines are produced each year by the Experiment Station for sale to Iowa growers. It is the policy of the Iowa Agricultural Experiment Station to release only those inbred lines which are being used in the superior hybrids that have been distributed for commercial production. In disposing of this seed to growers it would seem that the best interests of the corn improvement program might be served if the available seed stocks were released under two classifications designed to serve rather different needs. These two kinds of distribution, one of which may be thought of as the release of the "germ plasm" of the lines and the other as the sale of seed in quantity, are outlined below.

Sale of the Germ Plasm of Inbred Lines

For these distributions only hand-pollinated seed will be sold. Only small quantities of such seed are available but as long as they last requests will be filled in the order in which they are received. A small packet of a few seeds of any one line will be sold at a nominal price to cover the cost of handling and mailing.

Sale of Seed of the Inbred Lines in Quantity

Small quantities of seed of released lines, increased in isolated plots from hand-pollinated seed, will be sold by the Experiment Station for use in the production of foundation single crosses or for increase in isolated one-line plots. As is the case with single-crossed seed, the restrictions on the sale of inbred seed may differ from year to year, depending upon the available supply.

ONLY HYBRIDS OF DEMONSTRATED PERFORMANCE SHOULD BE GROWN

Not all hybrids are desirable. Some have proved to be outstanding, while others are not equal to the better open-pollinated strains. Rather remarkable records made by some hybrids in yield tests have caused a demand for hybrid seed which has exceeded the supply. Consequently, seed has been offered as hybrid which either is not hybrid at all or not of proved superiority. Seed saved from a hybrid crop is not hybrid in the strict sense and generally its value in producing satisfactory yields has not been demonstrated. Considerable experimental evidence shows that this advanced generation or F_2 seed is likely to produce from 5 to 40 percent less than the first-generation or F_1 seed, planted under the same conditions.

The corn grower will do well to buy seed of only those hybrids which have demonstrated their superiority. Seed of a number of hybrids developed by private agencies has constituted the major portion of hybrid seed available for planting in Iowa up to the present time. Many of these hybrids have been thoroughly tested in the Iowa Corn Yield Test. Pros-

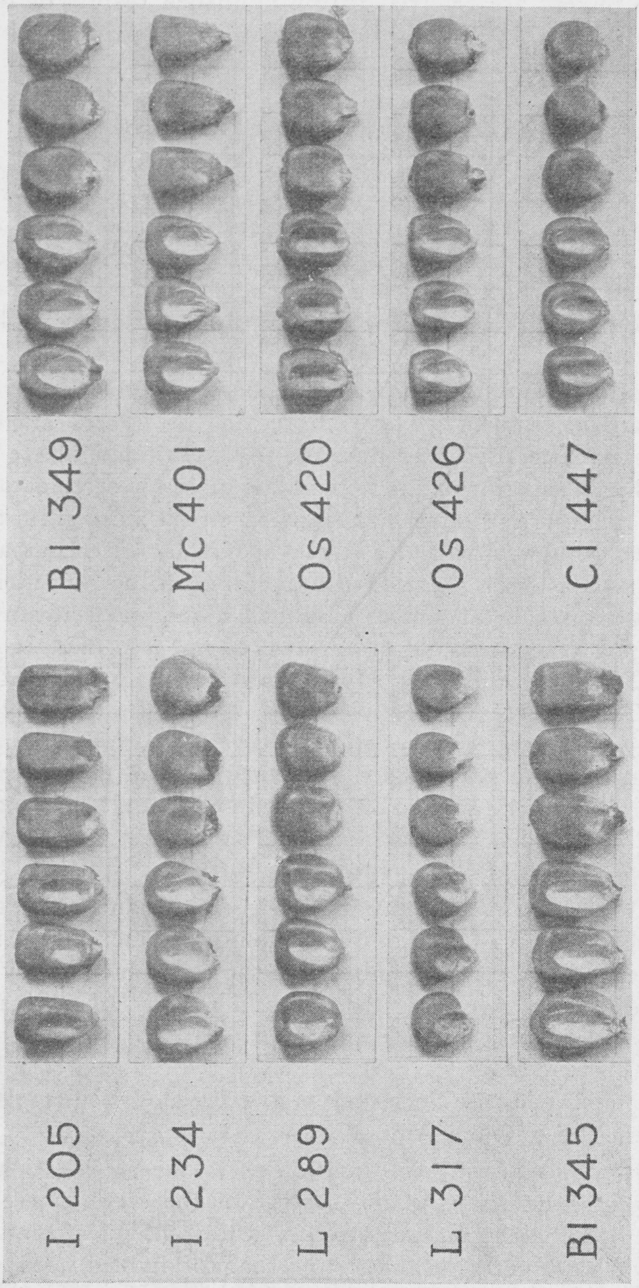

Fig. 30. Typical kernels of the 10 inbred lines involved in *Iowa Hybrids* 931, 939, 942 and 13.

pective buyers are referred to the published results of these tests which may be obtained from the Iowa Agricultural Experiment Station at Ames.

CERTIFIED HYBRID SEED CORN

Seed of hybrids with a satisfactory performance record may be endorsed by an impartial agency. In Iowa this agency is the Iowa Agricultural Experiment Association and its endorsement is known as "certification." Certified hybrid seed corn gives the purchaser of such seed some assurance of its being a superior product and encourages the production of high quality seed.

Certain requirements must have been met before hybrid seed can be certified. The pedigree of the hybrid must be known to the certifying agency, and this hybrid must have performed in a superior manner. To be eligible for certification a hybrid must have produced at least 10 percent more grain than the open-pollinated varieties with which it has been compared, must have at least equaled the average of the varieties in lodging resistance and must have had a combined advantage in lodging resistance and grain yield of not less than 25 percent. These records must have been made in the Iowa Corn Yield Test either as a section entry in 2 of the past 5 years or as a district entry in 5 of the past 6 years. The hybrid must have no characteristics which obviously make it on the whole undesirable for the section or district in which its performance record was made.

Certified seed of inbred lines, foundation hybrids and commercial hybrids may be produced either by hand pollination or in isolated plots. Seed of foundation or commercial hybrids, however, will be certified only when the certifying agency has ascertained that not more than ½ of 1 percent of pollination was by other than the indicated pollen parent. The complete regulations covering the certification of hybrid seed corn may be obtained from the Secretary of the Iowa Agricultural Experiment Association, Ames, Iowa.

A blue tag, carrying information as to the certification requirements and showing the section of the state where the hybrid has met these requirements, is the symbol of certification when properly attached to a bag of hybrid seed corn

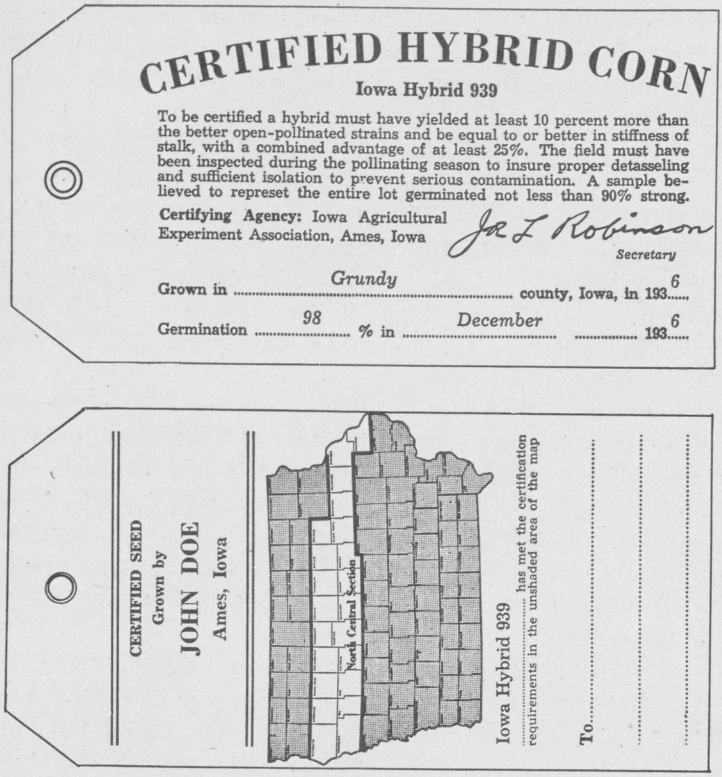

Fig. 31. This blue tag is attached to every bag of certified hybrid seed corn.

(fig. 31). About 50,000 bushels of hybrid seed eligible for certification were produced in Iowa in 1934, 55,000 in 1935 and 100,000 in 1936[6]. It is estimated that the total production in 1936 was about 185,000 bushels or enough to plant about 13 percent of the total corn acreage in Iowa.

A SUGGESTED PLAN FOR COOPERATIVE LOCAL PRODUCTION OF HYBRID SEED CORN

It is possible for the individual farmer to produce enough seed of each of the four inbred lines, two single crosses and the double cross for planting his corn acreage. Small quantities of seed are needed, however, and it would seem better to concentrate the seed production of many farmers under the supervision and responsibility of one individual.

[6] These figures were furnished by Joe L. Robinson, Secretary of the Iowa Agricultural Experiment Association.

Production of inbred and single-crossed seed is a specialized business. Much care and attention are required. During the pollinating season such attention must be given at the proper time; it cannot be put off until "tomorrow."

If a local cooperative association could be organized and the work of hand-pollinating, detasseling and caring for the seed concentrated under the responsibility of one individual who is interested and who makes this his first duty, the production of hybrid seed would become a relatively simple problem. An association might well comprise the corn growers in a single township. The average township in Iowa has about 6,000 acres of corn and requires about 1,000 bushels of seed. This quantity of seed can be produced on one field of 40 acres or less. It is much easier to locate one such field, properly isolated, than to find 40 1-acre fields, each properly isolated.

Each farmer could take his supply of double-crossed seed direct from the field and dry and store it in the usual way. This would eliminate the necessity for an expensive drying plant and enable the farmer to get good hybrid seed corn at a moderate cost.

It is possible that in the future certain individuals will devote their efforts solely to the increase of pure seed of some of the inbred lines, while others will produce nothing but foundation seed of one or more of the single crosses, supplying such seed to those who may wish to make double-crossed seed for general planting.

A cooperative association might do well to purchase its needed supply of single-crossed seed, limiting its seed growing activities to the production of the commercial seed for general planting.